ATEC
A Cadiz Solution

Hexavalent Chromium (Cr(VI)) Removal from Groundwaters

Drinking Water Treatment Whitepaper

Background & Overview

Hexavalent chromium (Cr(VI)) can be found in groundwater from naturally occurring deposits, or stemming from industrial pollution from steel production, electroplating and other industries.

It is a known toxic contaminant in drinking water with several serious potential health effects. A summary of these health risks is as follows:

1. **Carcinogenic Risk**: long-term exposure is linked to increased risk of cancer, particularly stomach cancer, as shown in animal and some human studies.
2. **Digestive System Issues**: may cause stomach ulcers, intestinal irritation, and other gastrointestinal problems with prolonged exposure.
3. **Liver and Kidney Damage**: Chromium-6 can accumulate in the liver and kidneys, leading to organ damage over time.
4. **Reproductive and Developmental Harm**: animal studies suggest possible reproductive toxicity, including effects on fertility and developmental issues in offspring.
5. **Skin Reactions**: Direct contact or ingestion can lead to skin rashes, ulcers, or allergic reactions in sensitive individuals.

A famous case of industrial contamination occurred in Hinkley, California, in the 1990s. Pacific Gas and Electric Company (PG&E) used Hexavalent chromium (Cr(VI)) to prevent rust in cooling towers at a gas compressor station. The contaminated water was discharged into unlined ponds, allowing it to seep into groundwater, which was the town's drinking water source. While working at a small law firm as a legal clerk, Erin Brockovich built a case connecting residents' serious illnesses to Cr(VI) contamination. In 1996, PG&E settled the case for $333 million, which at that time in U.S. history was the largest settlement ever paid in a direct-action lawsuit. The case was later made famous by the 2000 film Erin Brockovich, starring Julia Roberts, who won an Oscar for the role.

Hexavalent chromium (Cr(VI)) is not consistently removed by standard water treatment processes, so it requires a specialty approach for effective removal to ensure safety and regulatory compliance. There are several potential treatment approaches. This whitepaper summarizes available technologies for Cr(VI) removal from utility-scale drinking water systems and recommends an approach to determining the best solution for a water utility.

Hexavalent Chromium (Cr(VI)) Occurrence

Cr(VI) is an oxidized form of chromium that can exist as chromium (VI) oxide, chromic acid, chromate or dichromate in groundwater. Hexavalent chromium can exist in natural groundwaters or in waters that have been affected by local industrial activities. In natural groundwaters, hexavalent chromium is thought to be oxidized by manganese dioxide-containing minerals from naturally occurring chromium (III)-bearing minerals. The presence of Cr(VI) is dependent on the pH and oxidation conditions of the groundwater.

Chromium is a metal found in natural deposits of ores containing other elements, mostly as chrome-iron ore. It is also widely present in soil and plants. Under most conditions, natural chromium in the environment occurs as Chromium(III), or trivalent chromium. Under oxidizing conditions, alkaline pH range, and/or the presence of manganese dioxide and minerals containing chromium, part of it may occur as Cr(VI) dissolved in groundwater. Historic sampling of drinking water sources throughout California suggests that Cr(VI) may occur naturally in groundwater at many locations.

Chromium has two main oxidation states: trivalent chromium (Cr(III), chromium-3, Cr+3), and hexavalent chromium (Cr(VI), chromium-6, Cr+6). As a general rule, Cr(VI) is expected to predominate in highly oxygenated drinking water or when strong oxidants such as chlorine or even moderately strong oxidants like chloramine are present in water. At low Cr concentrations in typical drinking water conditions, Cr(VI) is present as monovalent HCrO4 – below pH 6.5 and divalent CrO4 2– between pH 6.5 to 10. At very low or no oxygen levels, Cr(III) is the dominant species, which will be in cationic (Cr+3, CrOH+2, or Cr(OH)2 +) or neutral (Cr(OH)30) form depending on the pH of the water. Cr(III) tends to be extremely insoluble (< 20 µg/L) between pH 7 and pH 10, with minimum solubility at pH 8 of about 1 µg/L.

*https://www.epa.gov/sdwa/chromium-drinking-water
**https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/SWRCBDDW-21-003_hexavalent_chromium.html

Hexavalent Chromium Water Quality Regulations

Federal Regulations*

As of 2025, there is no federal regulatory standard for Cr(VI). In 1991, the USEPA established national primary drinking water regulation with a maximum contaminant level (MCL) of a total chromium of 0.1 mg/l (100 µg/L)*. However, in 2010, USEPA initiated a reassessment of the health risks associated with Cr(VI) and total chromium. This assessment is still underway. In order to ensure that the greatest potential risk is addressed, the USEPA regulation assumes that a measurement of total chromium is 100 percent Cr(VI), the more toxic form. If tap water from a public water system exceeds this federal standard, the water utility provider is required to notify its customers but is not required to implement a treatment system.

California Regulations**

Over the past decade, California has set, repealed, and re-evaluated an MCL specifically for Cr(VI) to lower the exposure to this contaminant. In 2014, California first adopted a new MCL specific to Cr(VI) of 10 ppb that was lower than the total chromium limit. But then in 2017, the state court invalidated the 2014 MCL for Cr(VI) on grounds that the economic analysis that had been conducted to set the MCL was insufficient. Very few utilities implemented treatment during that 2014-2017 period when the MCL was in effect.

Fast forward to April 17, 2024, and California again adopted a Cr(VI) MCL at the originally proposed limit of 10 ppb after completing a new economic analysis. The MCL became effective on October 1, 2024 and allows a period of up to three years to meet the MCL, depending on the size of the water system as summarized in the following table:

System Size (Service Connections Served on Oct. 1, 2024)	Cr(VI) MCL Compliance Date
10,000 or greater	Oct. 1, 2026
1,000 to 9,999	Oct. 1, 2027
Fewer than 1,000	Oct. 1, 2028

Currently California has the nation's only drinking water MCL for Cr(VI).

Treatment Technologies

Hexavalent chromium (Cr(VI)) can be removed from water using a handful of proven treatment techniques. Determining the optimal treatment system for a particular site should be based on a holistic analysis of the following factors:

- Level of chromium present in the source water and other water quality parameters
- Treated water quality goals
- Competing and/or complementary treatment objectives
- Treatment byproduct disposal options

Treatment options for removal of Cr(VI) from drinking water include the following:

- Reduction followed by coagulation and filtration (RCF)
- Anion exchange (both strong-base and weak-base)
- Membrane filtration
- Adsorption
- Electrodialysis

Research was conducted by a collaboration of southern California drinking water utilities, the Water Research Foundation, and the EPA in 2016. The research project showed that weak-base anion exchange and reduction-coagulation-filtration were both capable of removing Cr(VI) to below 5 ppb for one utility's groundwater source. Other California utilities participated in additional studies and found that strong-base anion exchange was also a viable treatment for their particular groundwater sources, particularly if residuals disposal options were readily available for the ion exchange process byproducts.

Note: some research has indicated that it may be feasible to treat for Cr(VI) in-situ, meaning in the groundwater aquifer itself, prior to withdrawal (pumping). The approach relies on creating geochemically reducing conditions in an aquifer to remove Cr(VI) from groundwater. The goal is to form chromium hydroxide (Cr(OH)3) which has a low solubility in water and may therefore be immobilized in the aquifer matrix. This methodology involving injecting chemicals into the groundwater aquifer is considered experimental, and is beyond the scope of this whitepaper.

Comparison of Treatment Technologies

In establishing the Cr(VI) MCL, California's Division of Drinking Water designated Ion Exchange, Reduction/Coagulation/Filtration (RCF), and Reverse Osmosis as Best Available Technologies (BAT) — a designation under Health & Safety Code §116370 that allows utilities to implement these methods without additional pilot testing. Other promising options under consideration include membrane filtration, biological reduction, and zero-valent iron adsorption.

Table 31. Best Available Treatment (BAT) Alternatives for Hexavalent Chromium

Treatment Process	CA BAT*	Benefits	Drawbacks
Reduction – Coagulation – Filtration (RCF)	Yes	• Uses readily available technologies • Industry familiarity with process • Well understood & repeatable • Manageable & predictable lifecycle costs	• Residuals management • Verification of chemical dosing & residence times
Anion Exchange with Weak Base Anion (WBA) Resins	Yes	• Some resins may provide high removal capacities	• Resin lifecycle & disposal costs • pH dependent • Variations between resin manufacturers • Not well understood or repeatable
Anion Exchange with Strong Base Anion (SBA) Resins	Yes	• Well understood technology and process	• Brine lifecycle & disposal costs • Capacity loss after multiple regenerations

Reduction – Coagulation – Filtration (RCF)

RCF treatment has proven to be broadly applicable to most water utility applications, and tends to provide the most cost-effective approach when compared to other methods once the entire life cycle cost is analyzed. The treatment process works in these main steps:

1. Reduction: a chemical reductant (commonly ferrous sulfate, $FeSO_4$, or other ferrous compounds) is added to the water. This converts the toxic, soluble Cr(VI) into the much less toxic and less soluble Cr(III).

2. Coagulation: as Cr(III) forms, it tends to stay dissolved, so a coagulant (like ferric chloride or alum) is added to cause the Cr(III) and other fine particles to aggregate into larger clumps (called flocs).

3. Filtration: the water is then passed through a filtration system that traps the flocs containing Cr(III) and other impurities, effectively removing them from the water.

4. Backwashing: the filter bed is then backwashed to remove the accumulated flocs from the system, creating a sludge that is then managed properly to ensure the chromium is safely and effectively sequestered.

Key steps in the process are ensuring the fully reduction of Cr(VI) to Cr(III) during the reduction step, ensuring proper pH control (typically between pH 6 and 8) to optimize the reduction and coagulation reactions, and proper residuals management.

Reduction

Reducing Cr(VI) to Cr(III) is relatively easy to accomplish. It involves providing a source of electrons (reductant) so that Cr(VI) can be reduced to Cr(III). Potential reductants include stannous chloride, sulfide, sulfite, and ferrous iron compounds. Ferrous iron coagulants are among the most effective reductants for treating Cr(VI) in drinking water. The Cr(VI) reduction reactions involving ferrous iron is shown in Equation 1.

Equation 1: 3 Fe(OH)2 + CrO42- + 4 H2O => 3 Fe(OH)3 + Cr(OH)3 + 2 OH-

Coagulation

After Cr(VI) is reduced to Cr(III), coagulation promotes the formation of larger flocs for removal. Common coagulants include ferric chloride, alum, ferric sulfate, and polyaluminum chloride (PACl). Among these, ferric chloride is generally the most effective for chromium treatment due to its ability to form dense, fast-settling flocs and contribute additional iron for complexation. Alum is also used but tends to produce lighter flocs and is more sensitive to pH. Coagulant choice depends on water chemistry, with jar testing often used to optimize dosage. In many cases, polymers are added to enhance floc strength and filtration performance. Ferric-based coagulants are preferred when minimizing sludge volume and improving filtration efficiency, especially when paired with manganese dioxide media.

Filtration

Following coagulation, water flows through granular media filters that capture flocs containing Cr(III) and other particulates. ATEC systems commonly use manganese dioxide-coated media, which offers high removal efficiency and longevity due to catalytic surface reactions. Media selection can also include sand or anthracite, depending on system goals. Filters are housed in pressure vessels and often skid-mounted for rapid deployment. Regular backwashing removes accumulated solids and restores performance. ATEC's internally manifolded designs use treated water for backwash, reducing the need for pumps and minimizing waste. This approach improves reliability, simplifies operation, and reduces lifecycle costs.

Traditional Approach to RCF Treatment

Since 2005, a private water utility has been operating a Cr(VI) removal facility in California using a traditional RCF process (see Figure 3-1) that works by first reducing Cr(VI) to Cr(III) by dosing ferrous chloride into the water. After a few minutes of reaction time in a mixing tank, the water is aerated in another mixing tank to precipitate the iron and then the reduced Cr(III) is sent to a gravity clarifier tank and then pumped to the filter system (in this case a microfiltration membrane is used for the filter, but more commonly a media filter is utilized) to remove solids. Because oxygen precipitates iron quickly, but is slow to oxidize chromium, the process successfully reduces and removes Cr(VI) and Cr(III) below 10 µg/L as shown in Figure 3-2.

Figure 3-1. Traditional Cr(VI) Removal with Reduction/Coagulation/Filtration Process

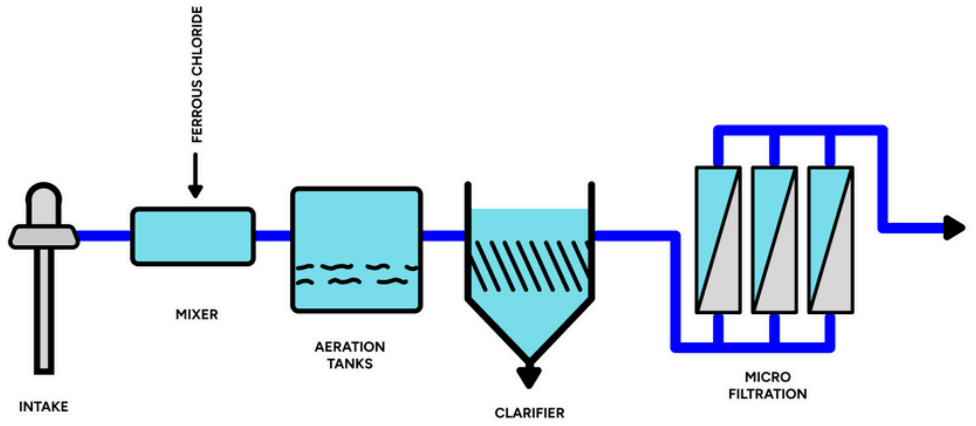
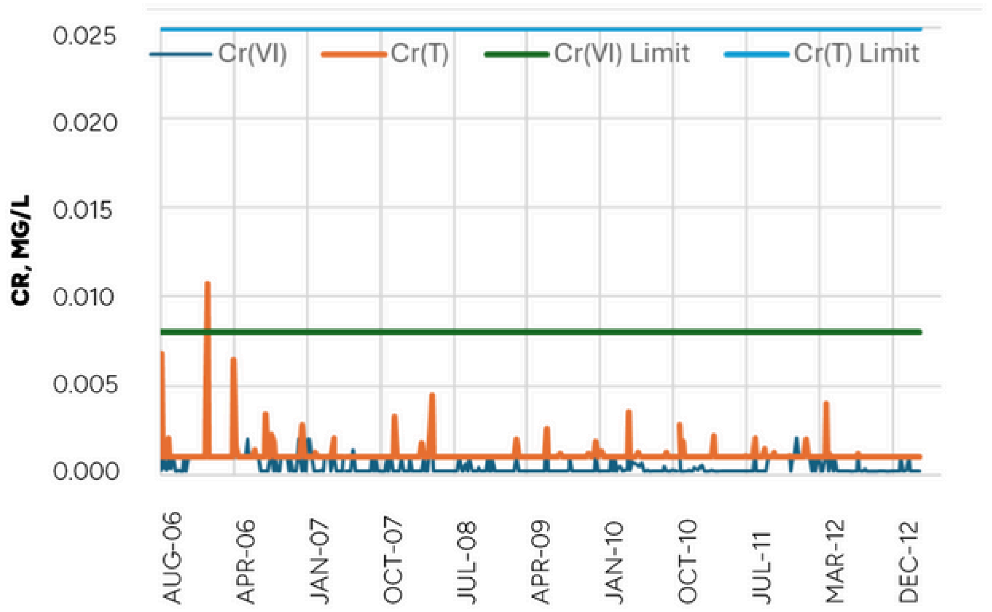


Figure 3-2. This treated water Cr(VI) and Total Chromium Concentrations from 2005 through 2012 after Microfiltration for a Confidential Client Demonstrates a Long Operational knowledge based for Reduction, Coagulation and Filtration.

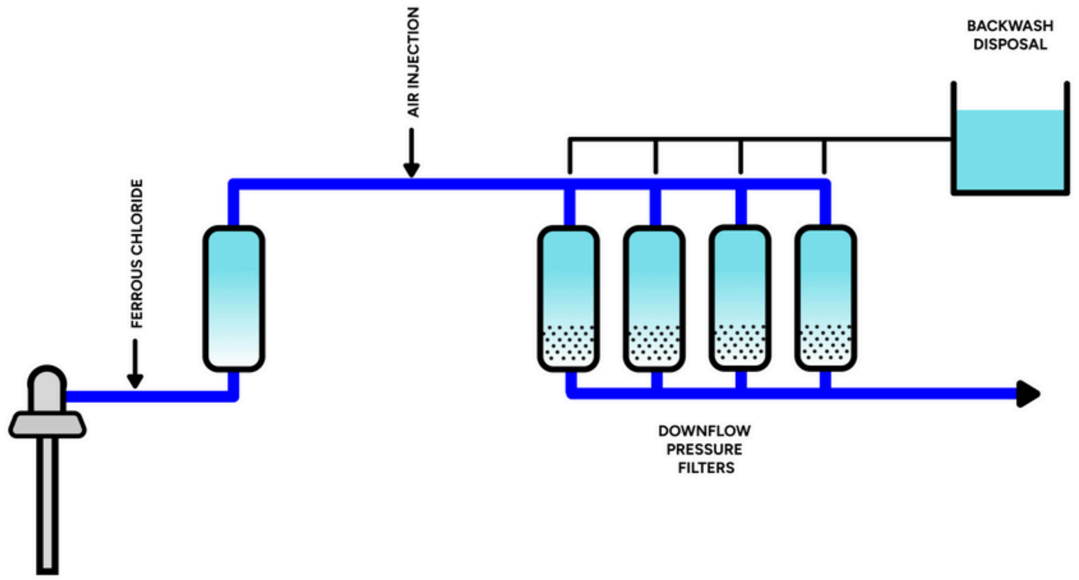


A Simplified Approach to RCF Treatment

Figure 3-3 illustrates a streamlined treatment approach to removing Cr(VI) using Reduction/Coagulation/Filtration (RCF) which is recognized as an EPA Best Available Technology (BAT). The system begins with the addition of a reducing agent, typically ferrous chloride ($FeCl_2$), to the raw water, which provides ferrous iron (Fe^{2+}) to reduce soluble and toxic Cr(VI) to insoluble and less toxic Cr(III). A pipeline contactor or contact tank is included to provide sufficient residence time for reduction kinetics, ensuring complete conversion of Cr(VI) to Cr(III). An oxidation step using air or sodium hypochlorite can then be used to promote the formation of ferric hydroxides ($Fe^{2+} \rightarrow Fe^{3+} \rightarrow Fe(OH)_{3(s)}$), which are an effective coagulant that drives floc formation. These flocs aid in adsorbing chromium and capturing other suspended particles which can then be removed in a series of downflow pressure filters.

The filters are periodically backwashed to remove the accumulation of suspended solids containing chromium. Backwash wastewater is supplied by the distribution system pressure and is directed to a disposal system for proper solids management. This streamlined configuration avoids the need for clarifiers or external backwash pumps, delivering a compact, cost-effective, and scalable solution for Cr(VI) treatment in groundwater.

Figure 3-3. A Simplified Approach to Hexavalent Chromium Removal with Reduction/Coagulation/Filtration



Simplified RCF Treatment Pilot Testing

Cadiz Pilot Test

A pilot study was conducted by CH2MHill (now Jacobs) for private water company Cadiz Inc. investigating the feasibility and costs of treating a large volume of groundwater as part of a wholesale water supply system to several communities in Southern California. Since the project would necessitate transferring the water through existing water canals, treatment of the water to remove both chromium and arsenic would be necessitated so as not to degrade the native water quality present in the aqueducts. ATEC water systems of Hollister, California (established 1982) provided the pilot system to verify effectiveness and develop the design criteria for an anticipated full scale treatment system at the site.

A reduction-coagulation-filtration (RCF) treatment plant was determined to be the most cost-effective option for the site due to the large treatment capacity of 80 million gallons per day (MGD). In comparison, weak-based ion exchange would require periodic replacement of the resin, and strong-based ion exchange would require periodic regeneration with sodium chloride or other regenerant chemicals, which would have very high transportation and disposal costs due to the remote Mojave Desert location of the Cadiz site.

The treatment system that was demonstrated at the Cadiz site is a simplified version of RCF treatment when compared to the traditional RCF treatment approach previously discussed in this whitepaper. The reduction from Cr(VI) to Cr(III) occurs in a pipeline, rather than in a tank with a mixer. The inherent turbulence of the flow in the pipeline was proven to provide adequate mixing without a separate tank being necessary. Similarly, the oxidation of iron occurs in a pipeline rather than in a mixing vessel or reactor tank. The reasons to use a pipeline for the reduction and oxidation reactions at this particular site are two-fold. First, Cadiz already must construct a pipeline to transfer the water from the wells to the treatment plant site, which reduces the treatment infrastructure costs considerably, and second, by using a pipeline reactor, the pumped water can be maintained under pressure, which eliminates the need for re-pumping and storage. It was determined that the reduction and coagulation stages of the treatment process could take place in either piping or vessels within the treatment process, depending on the site specifics.

For the filtration stage of the process for removal of the flocs, it was demonstrated that using pressure filters with manganese dioxide media based on the ATEC system is highly effective at removing the flocs. ATEC has a long history of successful cost-effective operations for treatment of iron, manganese and arsenic in groundwater and their manufacturing facility is based in California.

Las Lomas Station 305 – California Water Services

Las Lomas is an unincorporated community and census-designated place (CDP) in Monterey County, California with a population of about 3,000 people as of the 2020 census. California Water Services (Cal Water), an investor-owned water utility, has provided water utility services to the community since 1988. The water system utilized groundwater produced by two wells that is then treated and delivered to customers through a distribution system that includes three storage tanks and four booster pumps. In 2014 it was determined that the Las Lomas Station 305 well had Cr(VI) contamination above the MCL, so Corona Environmental Consulting was contracted to determine an effective treatment modification for the site. The site was already utilizing an iron and manganese treatment system supplied by ATEC Water Systems. Pilot testing was conducted at the site and determined the following:

- **Reduction**: reduction of Cr(VI) to Cr(III) would occur in approximately one minute at this site
- **Coagulation**: chlorine rather than air could be utilized to oxide iron for improved coagulation and formation of strong flocs
- **Filtration**: the existing manganese dioxide media could effectively filter the flocs, as well as continuing to effectively remove iron and manganese

Using these design criteria conclusions from the pilot, the system was then modified to provide the needed chemical feeds and contact time for reduction and chemical dosing for the coagulation step. The existing filtration was already in place and effective.

California Water Service Company has been successfully operating the Las Lomas Station 305 Water Treatment Facility since 2016.

ATEC Water Systems Background and Experience

ATEC Water Systems started business in 1982 by supplying media filtration systems for agricultural applications in central California. With ample competition for irrigation customers needing cost-effective filtration systems for severe-duty, outdoor water treatment applications, the company developed cost efficient means of building fully integrated pressurized filtration systems on skids complete with valving and controls that carries forward to today's business.

Multiple tanks, manifolded together at the top and bottom, are used in the design of the ATEC filters to provide an-internally-supplied source of treated backwash water, eliminating the need for a backwash pump or an external source of supply. This is an important cost saving feature, because backwashing requires upwards of 20 gpm/sq ft to fluidize the bed and adequately remove accumulated solids containing chromium and other contaminants. The tanks are also attached to a common skid, creating a straightforward means to load, transport, unload and install the treatment systems, helping to reduce overall construction costs for new treatment plants.

ATEC's systems also incorporate durable 3-way actuated valves and robust polychlorinated biphenyl (PCB)-based controllers to ensure precise and reliable automation of filtration and backwash sequences. These components are designed for long-term performance in challenging field environments, with minimal maintenance requirements. For systems requiring more advanced integration, ATEC offers optional PLC or SCADA-based control packages, enabling seamless communication with existing plant automation. These control options allow utilities to monitor system performance in real-time, automate compliance reporting, and optimize operations remotely, further reducing the need for on-site labor and enhancing overall operational efficiency.

In 1996, the company pivoted out of the irrigation market to focus on groundwater treatment for water utilities while keeping true to their roots of providing highly effective and cost-efficient solutions. Chromium removal systems are a logical continuation of this evolution. The company has adapted their strong history of providing iron, manganese and arsenic removal systems to water utilities by leveraging their existing skidded, turnkey filtration systems to offer the reduction, coagulation and filtration (RCF) stages of chromium treatment in a fully-integrated, turnkey skidded package. As many groundwater sources may have concurrent needs to remove iron, manganese and arsenic along with chromium, the company has successfully demonstrated that the same manganese dioxide filtration media that has been used extensively for iron, manganese and arsenic removal since 1996 in California, the U.S, and Canada by ATEC Water Treatment Systems can also be utilized effectively for chromium and these other contaminants in a single treatment system.

Utility	No. of Wells	Total Capacity (gpm)
Aromas WD	1	4100
Cadiz	1	100
California Water Service Company	18	22920
Campo Kumeyaay Nation	1	43
Carol Krieger Yard	1	15
City of Fresno	3	12400
City of Fullerton	1	350
City of Live Oak	5	17200
City of San Juan Bautista	2	1600
City of Soledad	1	4200
City of Watsonville	1	1500
City of Yuba	1	4200
Cobb Area County	1	40
Earthbound Farm LLC	3	725
East Bay Municipal	1	250
Empire Grand Oasis	1	300
Forest Lakes Mutual	1	20
Fulton Processors, Inc.	1	500
Garden Farms Community	1	150
Golden State Water	11	25500
Hilmar Cheese Company	2	2200
Islander Mobile Home	1	90
Iipay Nation of Santa Ysabel	1	60
Manchester Point Arena	1	90
Mesa Grande Band	1	50
Pechanga Band of Indians	1	250
Rio Vista Water	1	4500
San Francisco Public Utilities	2	896
San Lucas Water	1	17
San Miguelito Mutual Water Compa	1	300
Soquel Creek Water District	1	725
Sweetwater	4	6200
True Leaf Farms	1	210
Willow County Water	1	90

Figure 4. ATEC installations in the state of California by utility.

Proven Solutions for Hexavalent Chromium (Cr(VI)) Removal

At ATEC Water Systems, we understand the urgency and complexity of meeting California's strict 10 ppb MCL for hexavalent chromium (Cr(VI)). With more than four decades of experience in groundwater treatment, ATEC offers utilities a proven, cost-effective path to compliance through our Reduction/Coagulation/Filtration (RCF) systems.

Our technology is backed by real-world performance, with successful installations across California and the western U.S. ATEC systems are designed for simplicity, reliability, and scalability, incorporating internally manifolded pressure vessels, long-life filtration media, and low-waste backwash designs—all optimized to reduce lifecycle costs and streamline operations.

Whether you are evaluating treatment options, preparing for pilot testing, or designing a full-scale system, ATEC is ready to support your team with responsive technical guidance and custom-engineered solutions.

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